Selection and use of domain ontologies in Learning Networks for Lifelong Competence Development

PhD.Stud. Kornelia Todorova,
Department of Information Technologies, Faculty of Mathematics and Informatics, University of Sofia "St. Kliment Ohridski",
Sofia, Bulgaria,
E-mail: cornelia@fmi.uni-sofia.bg

Assoc.Prof. Dr. Krassen Stefanov,
Department of Information Technologies, Faculty of Mathematics and Informatics, University of Sofia "St. Kliment Ohridski",
Sofia, Bulgaria,
Phone: +359 2 8161 511 or +359 2 8656 157,
E-mail: krassen@fmi.uni-sofia.bg

A general problem in life-long learning is how to develop flexible and adaptive learning content, and how to choose and deliver the most appropriate learning activities for the learner. In order to solve this problem, we need to have the proper knowledge model, and clear interpretation how to use it. One possible solution is to use IMS Learning Design for modelling the learning process and ontologies for representing the domain knowledge and competencies. In this paper we present one specific approach for applying this solution, and one possible implementation of this approach. We also analyse possible technological tools to be used in such implementation, and give reasons for our choice. We describe the current results from this implementation, and outline the problems encountered, as well as the research challenges remaining to be solved.

Keywords: ontology, learning design, semantic Web, production rules, Protege, RuleML.

Introduction

In this paper we analyse how and why domain ontologies can be used in Learning Networks for Lifelong Competence Development (LN4LCD), and discuss the problem of reusing domain ontologies in different LN4LCD. Then we present an approach to solving this problem and give a scenario for experiments. We provide a comparison of ontology description languages and tools and select the language and tool that best match our needs. We discuss some current solutions and results and propose specific actions and ideas of how to proceed further.

1. Analysis of the knowledge frameworks for LN4LCD

A general problem in life-long learning is how to develop flexible and adaptive learning content, and how to choose and deliver the most appropriate learning activities for the learner. This problem is related to identifying and representing the learner's current knowledge and the competence level s/he wants to achieve, and using those to formulate a personal competence development plan for the learner.

There are several approaches for representing such types of knowledge [9, 11, 12, 20, 21], but two are gaining recently more importance: using standards (like the full set of IMS e-learning specifications) and applying ontologies and Semantic Web technologies for description and classification of the subject domain.

Ontologies are mostly used for modelling the domain knowledge. They can be used for modelling both learner's knowledge and different competence levels related to the domain. In addition to these two models, a suitable mapping engine is needed to compare them and generate a personal competence development plan for the learner, which can help him to achieve a specified competence level.

IMS Learning Design (IMS LD, [22]) is a standard, allowing instructional knowledge to be represented by using the concepts of Unit of Learning and Learning Activity. As it is outlined in [20, 21] among others, the combination of ontologies and IMS LD could bring enough power for modelling the knowledge in the LN4LCD, allowing enough flexibility and adaptability in the learning process. We also adopt this approach for knowledge modelling, and use IMS LD for modelling the learning process and ontologies for representing the domain knowledge and competencies.

Since flexibility is an important issue, our ontology has to be easy re-usable from different Learning Designs. In order to allow the generation of learning paths, the ontology needs to have mapping capabilities (to allow easy mapping between two knowledge representations).

2. Our Approach

In our approach the units of learning are indexed through IMS compliant metadata. The information about the relations and interdependency between the units of learning is formalized through the domain ontology, allowing the design of abstract and simplified views of training domains.

Each unit of learning can be linked to some concepts and relations from the domain ontology - the ones, which can be learnt at some level of proficiency by using that unit. This link is naturally represented by the metadata description of the corresponding unit of learning.

The learner's current knowledge (personal competencies) will be identified from his personal portfolio, personal information available, or through using some standard assessment techniques like tests. As a result, a student model will be created.

Thus for each competence level the learner wants to achieve, we can automatically map these two models and derive a competence development plan (learning path), expressed by a specific set of learning activities, using a specific set of units of learning. More than one possible learning path will be typically created for a learner. Those paths can be further analysed depending on different parameters (time needed, cost, quality, difficulty, etc.), and the best suitable learning path for the learner could be chosen.

We plan to experiment with our approach as part of the activities in the TENCompetence project [23]. We will use a prototype of the Computing Ontology [18], developed in the frame of the DIOGENE project [19], and two or three different learning designs, corresponding to different models of learning.

The Computing Ontology prototype is based on the SHOE formalism [8], and created in the Protégé editor [10]. The main problem with the prototype is that the reasoning part of the ontology is hidden in the DIOGENE system, and as a result is not reusable. Another problem is related to the existing relations, which actually contain not only domain knowledge, but also instructional knowledge. So, we need to re-design the existing ontology, separating the domain knowledge from the instructional knowledge, leaving the instructional knowledge as part of the learning design. In order to make the ontology reusable in different settings, we need to use an implementation tool, which combines the language representation power with the suitable inference engine, that can use not only the domain knowledge, but also the pedagogical knowledge expressed in the LD specifications.

Our next task is to choose the right tool for the ontology implementation.

3. Comparison of ontology description languages and criteria for selection of the most appropriate one

An ontology is usually composed of: classes of objects, a vocabulary of terms (instances), and various relations between classes or terms and classes. A critical step in ontology development is the selection of the most appropriate language for ontology description, and tool for performing the basic ontology operations.

Ontology languages can be divided in two major groups: traditional and web-based languages [1, 3]. Some traditional languages are Flogic, OCML and Ontolingua [17]. Other ontology languages like XOL [7], OIL [6], SHOE [8] are defined as web- based languages.
On the other hand, we have languages, used mainly to physically code some ontology formalism, which are named representation languages. The most widespread such languages are XML [4], UML, RDF.
Other languages like PIF and KIF [5] are used mainly for conversion between different ontology languages, supporting the process of interchange between different ontology formalisms.
We will extend this classification with new type of languages: rule-based, like RuleML [2] and WRL [13].
Of course, some languages can be included in more than one group. Some of the traditional languages have been extended with additional, flexible and interactively updated information, making them very close to Web-based languages, like OWL [15]. Some other languages combine characteristics of web-based and rule-based languages, as SWRL [14].
The extended classification of all types of ontology description languages, as explained above, is shown on Fig.1

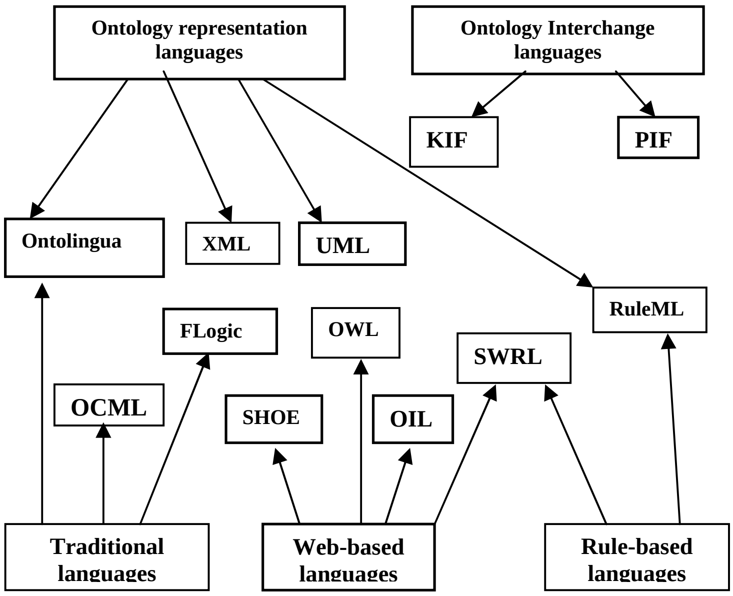

Fig.1 Ontology languages classifications

On the base of this classification, we analyse the most widespread ontology languages, using two main groups of criteria.

The first group (linked with the re-usability of the ontology model) organizes components of ontology like capabilities of language to describe ontology concepts, axioms, taxonomies and production rules.

The second group contains characteristics related to tools for ontology creation, validation, effective use and further development. It is related to the re-usability of the ontology operations.

Using different sources, including [24], we have collected and summarized the needed information in Table 1.

Characteristics	Traditional languages				Web-based languages			Rule-based language		
	Ontolingua	OCML	FLogic	LOOM	SHOE	OIL	OWL	RuleML	WRL	SWRL
Concepts	+	+	+	+	+	+	+	+	+	+
Taxonomy	+	+	+	+	-	-		+	/	/
Relations	+	-	-	-	+	+		+	+	+
Functions	+	/	+	-	-	+		/	-	+
Axioms	+	-	+	+	+	/	+	+	+	+
Instances	+	+	+	+	+	/	+	+	+	+
Production rules	-	+	-	+	-	/	+	+	+	+
Queries	-	-	+	/	+	-	/	+	+	+
Translators	-	/	/	+	+	+	+	+	/	/
Engines	/	-	+	-	-	/	/	/	+	+
Editors	+	+	-	+	+	+	+	/	+	+
User Interfaces	+	+	/	+	+	+	+	+	+	+

Table 1 Ontology languages comparison

Sign “+” is used to represent the availability of a feature, sign “-“ to represent a missing feature, and “/” is used to show missing or not definite information about a required characteristic.

On the base of analysis of the data presented in Table 1, it is clear that only rule-based languages are useful in our case, because only they guarantee re-usable ontology operations. Having in mind the syntax and tool used to define the prototype, SWRL seems to be the best choice, as (1) it is supported by the Protégé editor; (2) being based on OWL, it will be easier to convert and reuse different types of ontologies; (3) it is in very close relation and conformance with the RuleML initiative.

4. Implementation of ontologies in LD4LCD

Our next goal was to redesign the Computing ontology prototype using the Protégé editor and the SWRL language. We did this transformation using the Protégé features and made the transformation in two steps: first we transformed the ontology from SHOE to OWL, and then from OWL to SWRL.

Protégé can be used to develop rules for reasoning that allow providing of more effective and efficient support for life–long learning. (Fig. 2)

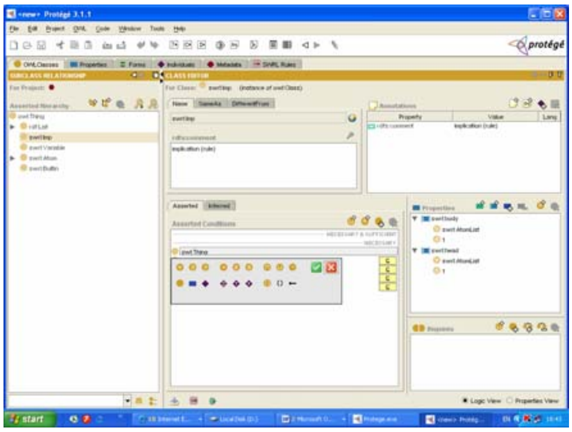

Fig. 2 Protege-OWL as a tool for editing of rule bases in SWRL

Algernon Protégé plug-in provides capabilities for rules manipulation as it is shown on Fig 3.

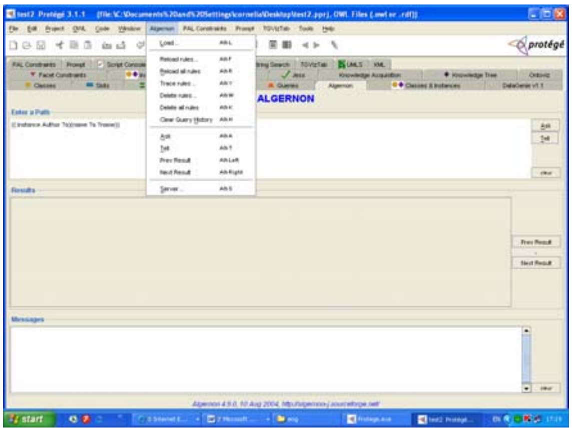

Fig. 3 Rules manipulation capabilities

Our new ontology has the possibilities for describing and using markup harmonization, rule syntaxes, rule modules and rule application. It extends rule expressiveness and rule semantics, and allows using RDF rules, ontology mapping and ontology coupling, rule validation and rule compilation. Other important features include using the capabilities for XML stylesheets, semiformal rules and rule documents.

The most important advantage is the ability to separate the knowledge and reasoning about a specific learning domain in one single tool, to make this independent of the learning design description, logic and use, and in this way to allow real interoperability and reuse of both the learning design and the learning domain ontology.

After we implemented the Ontology, our next steps are: (1) to combine the existing knowledge from the domain ontology, with the information and knowledge embedded in the learning design; (2) to formalise the mapping between the learner's model and competence model; (3) to generate different learning paths corresponding to the mapping of the models; and (4) to implement an algorithm for choosing the best learning path.

5. Conclusion

In this paper we presented an approach for using learning domain ontologies in LN4LCD. We discussed the problems with the reuse of such an ontology in different settings and different LN4LCD. On the base of one existing domain ontology, we chose the best ontology language and tool for using it in these different settings, and successfully transformed the ontology.

The main advantage for dynamic learning is reducing the amount of proposed learning content in the generated learning path, since it is created on the base of a learner profile and adaptive learning material delivery.

The IMS LD specification is proposed to assure interoperability of learning materials and processes related to knowledge management within different learning domains.

Our future work is related to research and development of the capabilities of the relational ontology languages and their implementation in domain ontology description, in order to achieve better reasoning and classification expression power with regard to knowledge management and sharing, and in particular the best possible coexistence of such tools with standard tools supporting IMS LD specification, in a common framework – LN4LCD.

We also formulated several practical experiments, which can be further investigated in the framework of the TENCompetence project [23].

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